

FUTURE PLANS FOR MEASURING THE GDH INTEGRAND ON THE DEUTERON AT HI γ S

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The HI γ S facility is presently undergoing an upgrade which will make measurements of the GDH integrand on the deuteron possible below pion threshold. The helical undulator system (OK-5) is presently being installed. This system will produce 100% circularly polarized γ rays. A booster injector is being built in Novosibirsk, and should be operating by mid-2006. This will eventually extend the energy of the HI γ S γ -ray beam up to pion threshold. A frozen-spin target is also being constructed. The neutron detection system will consist of an upgraded version of the BLOWFISH neutron detector array. Experiments will begin in late 2006. Details of the experiment and a preliminary schedule will be presented.

The Gerasimov-Drell-Hearn (GDH) sum rule connects the helicity structure of the photo-absorption cross section to the anomalous magnetic moment of the nuclear target, and is explicitly given by

$$I_T = \int_{\omega_{\text{th}}}^{\infty} d\omega \frac{\sigma_P(\omega) - \sigma_A(\omega)}{\omega} = 4\pi^2 \alpha s_T \left(\frac{\kappa_T}{m_T} \right)^2, \quad (1)$$

where σ_P and σ_A are the cross sections for absorption of polarized photons of energy ω and helicities parallel and antiparallel to the target spin s_T (in its maximum state), ω_{th} is the threshold photon energy for inelastic processes, α is the fine-structure constant, and m_T and κ_T are the target mass and anomalous magnetic moment, respectively.

Since the proton and neutron have relatively large anomalous moments ($\kappa_p = 1.793$ and $\kappa_n = -1.913$, respectively), the corresponding values of I obtained from Equation 1 are large, $I_p = 204.8 \mu\text{b}$ and $I_n = 232.5 \mu\text{b}$, while the deuteron, for which $\kappa_d = -0.143$, has a comparatively small $I_d = 0.652 \mu\text{b}$. As has been previously discussed, one should expect to observe the sum of the proton and neutron strengths (and more) in the deuteron above pion threshold, indicating that a large negative contribution of about this size ($-436 \mu\text{b}$) should exist below this threshold. In-

deed, Arenhövel² and others point out that the photo-disintegration channel, which is the only photo-absorption process below the pion threshold, gives a large negative contribution arising from the M1 transition to the resonant 1S_0 state just above the deuteron breakup threshold ($\omega - \omega_{th} < 100$ keV), since this state can only be formed if the deuteron spin and photon helicity are anti-parallel.

Although this low energy behavior has not yet been confirmed by a direct measurement, experiments using the linearly polarized beam at HI γ S have been used to make an indirect measurement. As previously discussed⁴, an approximate value of the GDH integrand can be deduced from the analyzing powers near threshold, since very few partial waves contribute at these low energies. The results of these measurements³ lead to the values of σ_P and σ_A shown in Fig. 1. There is good agreement with the theoretical predictions of Arenhövel².

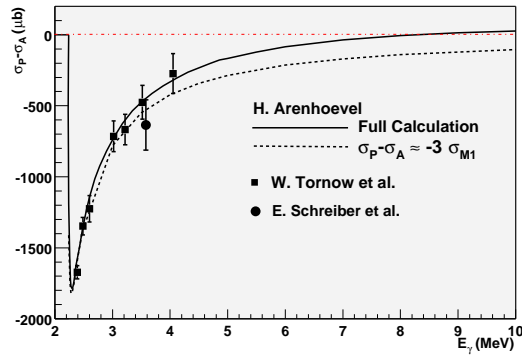


Figure 1. The values of $\sigma_P - \sigma_A$ deduced from the HI γ S photo-disintegration experiments are compared to theoretical predictions² using the complete theory (solid) and the same approximation (dashed) as was used in the data analysis. The data are based on the measurements from Schreiber and Tornow *et al.*^{1,3}.

The High Intensity Gamma-ray Source (HI γ S) facility produces γ -ray beams by back-scattering FEL photons from relativistic electrons inside a straight section of the 1.2 GeV Duke Free Electron Laser Laboratory storage ring. A schematic diagram of this facility is shown in Fig. 2 below. It is the fact that this process occurs inside the lasing cavity which is the reason for the resulting large γ -ray flux compared to all other existing facilities. The electron bunch in the storage ring passes through the undulators of the OK-

4 optical Klystron FEL. The mirrors of the optical cavity are placed so that the reflected stimulated light, generated by the magnets as the electrons pass through them, sits on-top of the electron bunch after it travels around the storage ring. The interaction of this light with the electrons in the bunch causes them to arrange themselves to be one optical wavelength apart. When this ordered bunch is further “wiggled,” coherent light is produced with an intensity proportional (ideally) to the square of the number of electrons in the bunch. Now the trick is to inject a second bunch so that this lased light, after reflecting off of the downstream mirror, collides head-on with the second bunch at the field free region between the two magnetic arrays of the OK-4. The Compton scattered photons are now γ rays which head for the target, as shown in Fig. 2.

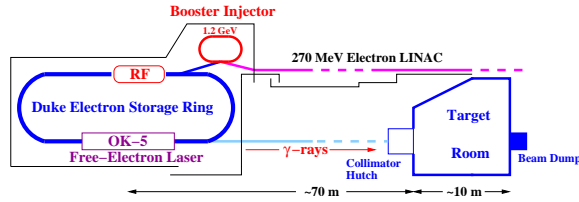


Figure 2. The HI γ S facility.

The HI γ S facility is currently undergoing an upgrade which will allow us to perform direct measurements of the GDH sum rule integrand. The upgrade consists of three main components which will eventually permit us to produce intense beams of 100% circularly polarized γ rays at energies up to 158 MeV. These components consist of: a new RF system, designed to allow for an increase in the amount of charge stored in a single bunch as well as to permit operation in the multi-bunch modes; a new helical undulator system, the OK-5, designed to produce linear and circularly polarized photons, and a booster injector, which will make it possible to replace lost electrons at full ring energy and thereby maintain the intensity of the γ -ray beam at full value. A schematic diagram of the upgraded HI γ S facility is shown in Fig. 3.

The present schedule calls for completion of all of these upgrades by March, 2006. The nuclear physics program will commence in June, 2006.

The upgraded HI γ S Facility will be used to perform a direct measurement of the GDH integrand using a frozen-spin polarized deuterium target. This target is being designed and constructed under the direction of Drs.

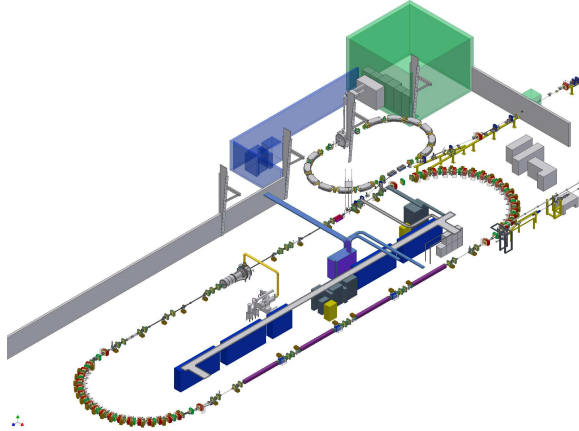


Figure 3. The fully-upgraded HI γ S facility showing the new RF system, the OK-5 helical undulator system (consisting of four 4-meter long arrays), and the 1.2 GeV Booster Injector.

Don Crabb and Blaine Norum of the University of Virginia. The target will be about 5 cm long and will provide about 10^{23} nuclei/cm². Due to recent breakthroughs in this technology, the target polarization is expected to be better than 85%.

Neutrons will be detected using the “Blowfish Array.” This detector array consists of 88 BC-505 liquid scintillator cells located on the surface of an 81 cm diameter sphere centered on the target in 8 uniformly spaced arms of equal azimuthal angle ϕ . The 11 cells in each arm are uniformly distributed between polar scattering angles θ of 22.5° and 157.5°. The excellent pulse-shape discrimination (PSD) properties of BC-505 provide a strong handle on neutral particle (neutron/ γ) identification down to about 200 keV_{ee}. This particle ID capability is complemented by time of flight (ToF) information obtained by using the time structure of the beam (one burst every 179 nsec). The combined effects of the PSD and ToF criteria totally eliminated background contributions in test runs at low energies. The broad coverage (25% of 4π steradians) of the detector and its ability to be rotated about the beam axis permit high statistical precision as well as an accurate determination of systematic effects. This system is presently undergoing an upgrade in which all photomultipliers and bases are being replaced to reduce noise and increase gain stability. An additional 40 detectors will also be installed to increase the coverage to $\sim 40\%$ of 4π .

The first phase of the $\text{HI}\gamma\text{S}$ study of the GDH integrand for the deuteron will map out the integrand between 5 and 50 MeV. A beam of 10^7 γ/s will allow us to map out this region to an overall accuracy of about 5% in approximately 300 hours of beam time. It is anticipated that this will be completed by the later part of 2007, after which the extension up to pion threshold will begin.

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